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FORM PTO-1300 (REV. 11-2000)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		ATTORNEY'S DOCKET NUMBER 3419-516 HSF	
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371				U.S. APPLICATION NO. (If known, see 37 CFR 1.5 10/088102	
INTERNATIONAL APPLICATION NO. PCT/CA00/01067		INTERNATIONAL FILING DATE September 22, 2000		PRIORITY DATE CLAIMED September 22, 1999	
TITLE OF INVENTION LOUDSPEAKER SYSTEM AND METHOD OF ASSEMBLING A LOUDSPEAKER SYSTEM					
APPLICANT(S) FOR DO/EO/US Stefan Hilbowicki and Gord van Kessel					
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:					
<p>1. <input checked="" type="checkbox"/> This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.</p> <p>2. <input type="checkbox"/> This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.</p> <p>3. <input type="checkbox"/> This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.</p> <p>4. <input checked="" type="checkbox"/> The US has been elected by the expiration of 19 months from the priority date (Article 31).</p> <p>5. <input type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2))</p> <p>a. <input type="checkbox"/> is attached hereto (required only if not communicated by the International Bureau).</p> <p>b. <input checked="" type="checkbox"/> has been communicated by the International Bureau.</p> <p>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).</p> <p>6. <input type="checkbox"/> An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).</p> <p>a. <input type="checkbox"/> is attached hereto.</p> <p>b. <input type="checkbox"/> has been previously submitted under 35 U.S.C. 154(d)(4).</p> <p>7. <input type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))</p> <p>a. <input type="checkbox"/> are attached hereto (required only if not communicated by the International Bureau).</p> <p>b. <input checked="" type="checkbox"/> have been communicated by the International Bureau.</p> <p>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</p> <p>d. <input type="checkbox"/> have not been made and will not be made.</p> <p>8. <input type="checkbox"/> An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).</p> <p>9. <input checked="" type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).</p> <p>10. <input type="checkbox"/> An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</p> <p>Items 11 to 20 below concern document(s) or information included:</p> <p>11. <input type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</p> <p>12. <input checked="" type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</p> <p>13. <input type="checkbox"/> A FIRST preliminary amendment.</p> <p>14. <input type="checkbox"/> A SECOND or SUBSEQUENT preliminary amendment.</p> <p>15. <input type="checkbox"/> A substitute specification.</p> <p>16. <input type="checkbox"/> A change of power of attorney and/or address letter.</p> <p>17. <input type="checkbox"/> A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.</p> <p>18. <input type="checkbox"/> A second copy of the published international application under 35 U.S.C. 154(d)(4).</p> <p>19. <input type="checkbox"/> A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).</p> <p>20. <input type="checkbox"/> Other items or information:</p>					

U.S. APPLICATION NO. (Section 37 CFR 1.51) 107/088102		INTERNATIONAL APPLICATION NO. PCT/CA00/01067		ATTORNEY'S DOCKET NUMBER 3419-516 HSF	
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21. <input checked="" type="checkbox"/> The following fees are submitted: BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)): Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO \$1000.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO \$860.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$710.00 International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) \$690.00 International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) \$100.00 ENTER APPROPRIATE BASIC FEE AMOUNT =				CALCULATIONS PTO USE ONLY	
				\$ 860.00	
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	\$	
Total claims	16 - 20 =		x \$18.00	\$	
Independent claims	3 - 3 =		x \$80.00	\$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)				+ \$270.00	
TOTAL OF ABOVE CALCULATIONS =				\$ 860.00	
<input checked="" type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				+ \$ 430.00	
SUBTOTAL =				\$ 430.00	
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
TOTAL NATIONAL FEE =				\$ 430.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property.				\$ 40.00	
TOTAL FEES ENCLOSED =				\$ 470.00	
				Amount to be refunded: \$	
				charged: \$	

a. ☐ A check in the amount of \$ _____ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 022095 in the amount of \$ 470.00 to cover the above fees.
 A duplicate copy of this sheet is enclosed.

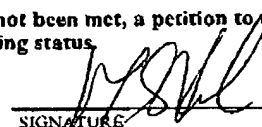
c. ☐ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any
 overpayment to Deposit Account No. _____. A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. Credit card
 information should not be included on this form. Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR
 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

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Patent Application Data Sheet**Application Information**

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Suggested

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Suggested Group Art

Unit::

CD-ROM or CD-R?::

Number of CD disks::

Number of copies of CDs::

Sequence submission?::

Computer Readable

Form (CRF)?::

Number of copies of CRF::

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10/088102
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**Title: LOUDSPEAKER SYSTEM AND METHOD OF ASSEMBLING
A LOUDSPEAKER SYSTEM FROM LOUDSPEAKER SUBASSEMBLIES**

FIELD OF THE INVENTION

This invention relates to loudspeaker systems, and more
5 particularly to loudspeaker systems including both passive speakers and
powered subwoofer speakers.

BACKGROUND OF THE INVENTION

There are a wide variety of different loudspeakers and
loudspeaker systems available. Where economy is a key concern and the user
10 will accept adequate performance over a narrower bandwidth, a single speaker
can be provided. The bandwidth is determined by the frequency response
characteristics of a speaker. A conventional loudspeaker has a drive coil
mounted for movement inside a fixed, permanent magnet. The drive coil is
connected to a cone, which is provided with a suspension. Movement of the
15 coil, drives the cone, which in turn generates the sound. Accordingly, the
speaker has a frequency response, in relation to an input signal, determined by
its electrical and mechanical characteristics. It has long been recognized that, for
a single speaker, it is virtually impossible to obtain an adequate or uniform
frequency response over a very large bandwidth.

20 Accordingly, to generate a uniform response over a wider
bandwidth, it is common to provide multiple speakers. A typical configuration
can include a speaker covering a middle range of frequencies, sometimes
termed a woofer speaker, and another speaker, usually smaller, covering a
higher range of frequencies, commonly called a tweeter. These two speakers
25 are usually passive speakers, in the sense that they are not separately powered.
As is well known, the power requirements for a speaker depend on the
speaker efficiency volume and bandwidth, and typical spectrum of a music
signal. Hence, a speaker covering lower frequencies requires greater power,
and it typically consumes 80% of the audio power. It is common to provide a
30 further speaker, commonly called a subwoofer, for covering the low frequency
range below 100 Hz, down to possibly as low as 20 Hz.

As a subwoofer can consume up to 80% of the power required

for the overall audio signal, it is common to provide powered subwoofers. This avoids having to generate large power levels at the audio amplifier, and distribute the required power to the subwoofer speakers. In a common, stereo arrangement, there are typically two speaker units or assemblies, for the left
 5 hand and right hand channels, each of which may or may not include a powered subwoofer speaker. For home theatre or surround sound systems, it is common to provide five or more individual speaker assemblies, so as to provide, at the front, left, centre and right front speakers, and the rear, left and right rear speakers. Again, each speaker assembly may include a powered
 10 subwoofer. The power required for each subwoofer is then generated in the speaker assembly itself.

At the present time, there are two basic techniques for providing such an overall speaker assembly comprising a powered subwoofer, a midrange speaker and tweeter. The first is to provide a complete, integrated
 15 unit including the three speakers. This has some attractions. It enables the manufacturer to select three speakers of comparable quality and compatible with one another, so as to provide uniform response over the entire, desired frequency range.

Additionally, for the subwoofer, it enables the manufacturer to
 20 set response characteristics, so these are accurately matched to the other speakers.

The disadvantage with this approach is that there is no flexibility, and for a quality speaker assembly, the cost can be quite high. It requires a customer to commit to a particular speaker configuration, and there is no
 25 possibility or option of upgrading part of the speaker assembly. If the customer wishes to upgrade his or her speakers, then the entire speaker assembly has to be replaced.

An alternative approach is to provide speaker assemblies, which can be considered as subassemblies, which together can cover the entire
 30 frequency range. Commonly, the passive speakers, i.e. the woofer (midrange) and tweeter speakers are provided in a single speaker enclosure or housing. The powered subwoofer, with its own power supply inputs for power and the audio signal, can then be provided as a separate unit in its own, separate speaker enclosure. This has the advantage that the user can select different

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5 combination of speakers depending upon his or her preferences, recognizing that speaker selection is always, to a significant extent, a matter of personal choice.

One advantage of separate subassemblies is that they provide greater flexibility in the initial selection. Also, they clearly enable a user or customer to upgrade the entire assembly by simply adding or replacing part of it. Thus, 10 just the powered subwoofer assembly could be added or replaced, or just the subassembly with the woofer and tweeter speakers.

A disadvantage with this arrangement is that, in order to get a true response from the speakers, it requires the controls for the subwoofer to be set, to match the other speakers, and it presupposes that this is indeed 15 possible. For example, controls for a powered subwoofer commonly include a volume or loudness control, phase control and frequency control, limiting the top end of the frequency range. This enables the speakers to be matched to provide the same loudness across the entire frequency range around the speaker assembly. Where the speakers are not from the same manufacturer, 20 it may not be easy to achieve a good match between them. Thus, the volume, phase control and frequency of the subwoofer need to be set, to correspond to the passive speakers. This is difficult to do.

Accordingly, what the inventor of the present invention has realized is that it is desirable to provide a speaker system, which combines the benefits 25 of the two approaches outlined above. That is a speaker system should provide the flexibility of having individual subassemblies, both to enable a customer to select desired subassemblies on initial purchase, and to enable addition, replacement or upgrade of just part of the overall assembly. At the same time, such an assembly should provide a mechanism or means to 30 enable the subassemblies to be combined, to form a complete speaker assembly, in which all the speakers are accurately and properly balanced with one another without the need for the user to set controls.

U.S. Patent No. 5,802,104, discloses a speaker system. It has a basic rectangular body including speakers and arms extending upwardly and 35 outwardly supporting additional tweeter speaker units or the like. It is intended to reduce baffle effect and increase direct sounds radiated from the speaker units to improve frequency characteristics in the middle frequencies.

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Published Japanese Application No. 04245796 discloses a speaker system combining an intermediate/high frequency speaker box and a low frequency speaker box. The intermediate/high frequency speaker box is configured so that its natural width is the same as its depth, and its depth and height are the same size as the low frequency speaker box. This enables the speakers to be joined together in at least two different configurations.

Published Japanese Application No. 11004491 discloses a speaker equivalent providing various configurations of guide sections to enable different elements of a speaker system to be mounted together.

None of these references address the issue of providing a family of speakers that can be combined in different configurations, with at least some of the speakers having different characteristics. Where speakers have different characteristics, there is the problem of ensuring that, whatever speaker configuration is chosen, appropriate drive signals are provided for each speaker.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a loudspeaker system comprising: a first speaker assembly; a second speaker assembly; and a coupling means providing a mechanical and electrical interconnection between the first speaker assembly and the second speaker assembly, the coupling means being adapted to interchangably connect the first speaker assembly to a different second speaker assembly having different audio response characteristics from the first-mentioned second speaker assembly, wherein the first speaker assembly includes an equalization circuit for providing a signal to the second speaker assembly, the equalization circuit having an output for connection to the second speaker assembly through the coupling means, wherein the equalization circuit is switchable to provide different outputs, each corresponding to the characteristics of a respective second speaker assembly.

Preferably, the first speaker assembly includes at least one first loudspeaker and a first amplifier therefor, and the second speaker assembly includes at least one second loudspeaker.

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The first speaker assembly can include a speaker adapted to cover a low range of frequencies, and the second speaker assembly can be adapted to cover a higher frequency range.

5 Advantageously, the coupling means provides a pair of electrical connections between the first and second speaker assemblies, for an audio signal from the first speaker assembly to the second speaker assembly, for driving the second speaker assembly. Moreover, the mechanical and electrical connections between the first and second speaker assemblies are preferably
10 integral with one another.

 In a preferred embodiment, the coupling means comprises two pairs of first and second coupling elements, with the first coupling elements being secured to the first speaker subassembly and the second coupling elements being secured to the second speaker subassembly, the coupling elements
15 being complementary and engagable with one another to provide a mechanical connection and being conductive to form pairs of electrical connections.

 The first speaker assembly can include an amplification and equalization circuit, for providing a drive signal to the low frequency speaker and can include a switch means enabling at least one of, the upper end of the
20 low pass frequency range, and the phase to be adjusted.

 More preferably, the amplification and equalization circuit includes a switch means for switching between at least one fixed filter mode, providing set parameters corresponding to a known second loudspeaker assembly, and
25 a manual mode in which the amplification and equalization circuit can be manually adjusted.

 Conveniently, the equalization circuit includes an output section having parameters relating to a desired loudspeaker response and the response characteristics of the low frequency speaker, at least one additional
30 section having parameters corresponding to a desired target response and parameters of a known second speaker system, thereby to give accurate

compatibility between the first and second loudspeaker systems.

In accordance with another aspect of the present invention, there is provided a loudspeaker system comprising: a first speaker assembly; a second speaker assembly; a connection means providing at least one of a mechanical connection and an electrical connection between the first and second speaker assemblies; and an equalization circuit in the first speaker assembly including at least two separate sections for adjusting the frequency response to match different second speaker assemblies; and a switch means for switching between the different sections of the equalization circuit.

A further aspect of the present invention provides a method of selecting and assembling a loudspeaker assembly, the method comprising the steps of:

(1) providing three or more first and second speaker assemblies, each first speaker assembly comprising a low frequency speaker and an amplifier for driving the low frequency speaker, and each second loudspeaker assembly comprising at least one passive speaker, and there being at least one first speaker assembly and at least one second speaker assembly;

(2) providing coupling means on the first and second speaker assemblies, enabling each first speaker assembly to be coupled to each second speaker assembly;

(3) permitting an end user to select a desired pair of a first speaker assembly and a second speaker assembly;

(4) coupling together the selected pair of first and second speaker assemblies.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

For a better understanding of the present invention and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 is a perspective view of two subassemblies of a complete speaker assembly in accordance with the present invention;

Figure 2 is a view of the passive speaker subassembly of Figure 1 in an inverted configuration;

Figure 3a is a perspective view of a pair of coupling elements;

The second subassembly 40 has an enclosure 42. Preferably, the

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speaker enclosures 40, 42 are visually compatible with one another. As for the first speaker enclosure 14, the speaker enclosure 42 is vented as indicated at 44, although such venting is not essential to the present invention.

5 A woofer and/or midrange speaker and a tweeter speaker would be provided in the speaker enclosure 42. Protective grills 46 and 47 are provided for the woofer and tweeter speakers respectively.

Now, in accordance with the present invention, to enable the two speaker subassemblies 12 and 40 to be combined together, the coupling arrangement 50 is provided. This coupling arrangement comprises two first
10 coupling elements 52 mounted on the top face 18 of the first subassembly 12, and two corresponding second coupling elements 54 mounted on a bottom surface 48 of the second subassembly 40. Each of the first and second elements 52, 54 comprises a stamped metal bracket.

The first elements 52, in cross-section, provide a trapezoidal
15 profile, with inclined side faces or first flanges 56, as shown in Figure 3. Additionally, this trapezoidal profile tapers along the length of the first elements 52. Correspondingly, the second elements 54 have two flanges 58, which extend outwardly and away from one another, at angles corresponding to the angle of the side faces 56 of the first element. This enables the first and
20 second elements 52, 54 to engage one another in a wedge-type action.

To secure the elements 52, 54 to the surfaces 18, 48, screws and nuts 62 are provided. These also secure the ends of electrical leads, indicated at 64, so as to make the electrical connections.

To positively locate the elements 52, 54 relative to one another, a
25 vertical stop 60 is provided at the narrower end of the first elements 52. Then, when the second elements 54 are fully engaged with the first elements 52, the second elements 54 abut the stops 60. The coupling arrangement 50 serves two functions. It provides a secure, mechanical interconnection between the two subassemblies, so as to secure them together as one unit. As shown, the two
30 subassemblies 12, 40 can be configured to be relatively tall and have relatively small footprint. This is aesthetically pleasing, but this coupling arrangement makes it possible for the top or second subassembly 40 to be securely mounted on the lower or first subassembly 12.

Additionally, as another significant aspect of the present

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invention, the coupling arrangement of the elements 52, 54 provides an electrical interconnection between the two subassemblies, for connection of the audio signal. Thus, the passive speakers in the second or top subassembly 40 are provided with an audio signal through the first and second elements 52, 54.

- 5 This has the additional advantage that this automatically ensures a correct phase relationship between the speakers of the two subassemblies 12, 14.

Referring now to Figure 4, there is shown an exemplary implementation of an equalization circuit, for incorporation with the subwoofer in the first speaker assembly 12. The equalization circuit is indicated
10 generally by the reference 70. The equalization circuit 70 has an input 72 for the signal for the subwoofer speaker connected to a connector 73. The input 72 is connected to a level control section 74, including an operational amplifier and a variable potentiometer 76, for adjusting the level of the signal.

The equalization circuit 70 includes, in effect, three separate
15 sections, identified as a first section 78, a second section 79 and a third section 80. Each of these sections 78, 79 and 80, in effect, includes two separate stages, one of which is identified at 82, for the section 78. Each of these parts 82 is generally common between the different sections 78, 79 and 80, in terms of the overall configuration of the individual components, but it will be understood
20 that different values are selected, to give desired frequency response characteristics for each part and for the sections overall.

Thus, the part 82 includes three separate amplifiers 84, and associated resistors, capacitors and power supply inputs.

The first and second sections 78, 79 have associated with them,
25 additional amplifiers 85 and 86 respectively, and the amplifier 85 is connected through as indicated at P2. These amplifiers 85 and 86 are provided with a signal from an amplifier section 87, which has an input connected to the output of the level control section 74. The amplifier sections 85, 86 and 87 all have characteristics related to the target frequency response.

30 The first and second sections 78, 79, as detailed below, are selected, when the first loudspeaker subassembly 12 is combined with a selected second subassembly 40. As such, they include frequency response characteristics determined from both the desired target frequency response and the frequency response of the passive speakers in the selected second

subassembly 40. For a perfect response, this requires adjusting seventeen parameters.

In effect, one first takes a model of the desired frequency response of the entire system, and then one mathematically subtracts from this
5 target frequency response, the response of the passive speakers in the selected second subassembly 40. This gives the desired response for the subwoofer in the first subassembly 12.

On analysis, this requires a fourth order high pass filter, which can be obtained from two second order filters coupled together. In effect, each
10 of the parts 82 provides a biquad filter, provided by the three operational amplifiers 84. This gives a biquad filter with a response characteristic which is a second order polynomial divided by a further second order polynomial.

As each of the sections 78, 79 and 80 has two parts 82, their response characteristics are multiplied together, to give, in effect, a fourth
15 order polynomial divided by another fourth order polynomial. As this is multiplied by the frequency characteristic of the subwoofer speaker, pole-zero cancellation can be used to obtain the desired response.

Here, the outputs of the sections 78 and 79 are connected to respective outputs 88 and 89. A further input section 100 for an alternative
20 input signal, detailed below, has an output 102. The outputs 88, 89 and 102 are connected to a switch 92 actuated by the switch knob 28 of Figure 1. The switch 92 has an output 94, connected to an input of the third section 80. The third section 80 again has, in effect, two parts 82, comparable to the sections 78 and 79. The parameters of the section 80 are selected to compensate for the
25 frequency characteristics of the subwoofer.

The derivation of the circuit of Figure 4 will be better understood by reference to Figures 7 and 8, which show schematically the derivation of the transfer function.

A loudspeaker can be considered as a band-pass filter. For
30 known reasons, it cannot reproduce the full range of frequencies. In practice, the most difficult part in loudspeaker design is to assure the low frequency reproduction which is the focus of this analysis.

For simplicity, one can assume that a loudspeaker is a high-pass filter; in effect, there is no difficulty in providing a frequency range that extends

well beyond the upper end of audio frequencies that can be heard by humans. To extend the range of the lowest frequencies, it is conventional to add another speaker called a subwoofer. The subwoofer bandwidth has to be properly chosen so both speakers together represent desired characteristics. It is desired
5 that such a system presents itself as another high-pass filter with a lower cutoff frequency. The cutoff frequency does not fully characterize the filter, a filter order and shape also have to be specified. What is required for the present invention is a subwoofer frequency response that when added to the speaker frequency response gives a projected or desired high-pass filter characteristic.

10 It is assumed that one wants to design a 6th order high-pass system comprising a 4th order speaker and a subwoofer whose passive section is a 4th order filter also. This is indicated schematically in Figure 7, where 200 indicates the speaker and an electronic filter 202 is shown connected to the subwoofer 204.

15 Therefore, what is required is an electronic filter with characteristic that satisfies the above requirements. In the following analysis, the following term are used.

SPK(s) - speaker response (Laplace)
SUB(s) - subwoofer response, its passive part
20 ELF(s) - electronic filter response, includes equalization
TOT(s) - total response
ALP(s) - all-pass filter response

From Figure 7, the equation for the circuit shown can be written as:

$$\text{TOT}(s) = \text{SPK}(s) + \text{ELF}(s) * \text{SUB}(s) \quad (1)$$

25 Rearranging gives:

$$\text{ELF}(s) = (\text{TOT}(s) - \text{SPK}(s)) / \text{SUB}(s) \quad (2)$$

The 6th order filter can be considered as cascade connection of three 2nd order filters. Similarly, a 4th order filter can be considered as a combination of two

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2nd order filters.

Thus:

$$\text{SPK}(s) = \text{spk1}(s) * \text{spk2}(s) \quad (3)$$

$$\text{SUB}(s) = \text{sub1}(s) * \text{sub2}(s) \quad (4)$$

- 5 where: $\text{spk1}(s)$, $\text{spk2}(s)$, $\text{sub1}(s)$, $\text{sub2}(s)$ are 2nd order components of appropriate filters.

Additionally, as $\text{TOT}(s)$ is a 6th order filter, it can be represented as:

$$\text{TOT}(s) = \text{tot1}(s) * \text{tot2}(s) * \text{tot3}(s) \quad (5)$$

where: $\text{tot1}(s)$, $\text{tot2}(s)$, $\text{tot3}(s)$ are 2nd order components of $\text{TOT}(s)$.

- 10 By putting these 2nd order filter components from equation (3), (4) and (5) into equation (2), the equation (2) can be solved. The resulting filter $\text{ELF}(s)$ has some drawbacks. The slope of its low-pass characteristic is in most cases not sufficient and cannot be controlled. The inventor has realized that introduction of an additional filter, as all-pass filter, yields a desired control over subwoofer
15 low-pass response.

Thus $\text{TOT}(s)$ is represented by:

$$\text{TOT}(s) = \text{tot1}(s) * \text{tot2}(s) * \text{tot3}(s) * \text{ALP}(s) \quad (6)$$

$\text{ALP}(s)$ is an all-pass filter that does not change total frequency response but only modifies its phase.

- 20 Equation (2) can now have the form:

$$\text{ELF}(s) = \frac{\text{tot1}(s) * \text{tot2}(s) * \text{tot3}(s) * \text{ALP}(s) * \text{spk1}(s) * \text{spk2}(s)}{\text{sub1}(s) * \text{sub2}(s)} \quad (7)$$

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or

$$ELF(s) = [tot3(s) * ALP(s) - \frac{spk1(s)}{tot1(s)} * \frac{spk2(s)}{tot2(s)}] * \frac{tot1(s)}{sub1(s)} * \frac{tot2(s)}{sub2(s)} \quad (8)$$

5 From equation (8) the diagram of Figure 8 is derived.

Referring to Figure 8, this shows two blocks or sections 206, 208 connected in series to a subtraction unit 214. Correspondingly, there are two further blocks 210, 212 connected in series to the subtraction unit 214. The various blocks or sections have the transfer function shown. Thus, each of the
 10 blocks 206, 208 and 210 has a transfer function of a second order filter, while the block 210 has the all-pass transfer function ALP(s).

From the subtraction unit 214, the signal is connected through blocks 216, 218 to the output. The blocks or sections 216, 218 have a second order of transfer functions indicated.

15 It will be understood that Figure 8 corresponds with the circuit of Figure 4. Thus, as indicated in Figure 8, the block 206 corresponds to section 82 in Figure 4. Generally, blocks 206 and 208 equate to section 78; for an alternative speaker, blocks 206 and 208 could equate to section 79. Blocks 210 and 212 equate to sections 87 and 85 respectively. Blocks 216 and 218 equate to
 20 section 80. For use in a conventional mode, block 100 replaces blocks 206, 208 and 212 of Figure 8.

Only blocks 206, 208 and 212 are related to speaker response. Only these blocks will need to be changed, when a different speaker is to be used.

25 It will be understood that the blocks 206, 208, 216 and 218 all have transfer functions with generally similar form. As such, they can be constructed using similar components in a similar arrangement. The desired transfer function values can be obtained by setting key components to required values.

30 Turning back to the section 100, this includes a first part 104, including ganged potentiometers 106, for adjusting the low pass frequency response. This first part 104 receives an input from the amplifier section 87, and has its output connected to further amplifiers 108. One of the amplifiers 108 has

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a switch 110 for adjusting the phase by 180°, while the other amplifier 108 simply acts as an adder, for adding the two alternative signals, as only one signal will ever be present, this amplifier 108 simply passes on whichever signal is present.

5 The connector 73 has an alternative input 112, for receiving an input signal. This is then fed through amplifiers 114a, 114b, and one can note that amplifier 114b provides a similar function to the amplifier section 87.

 Thus, in use, the switch 92 can be used to select either one of the sections 78, 79, dependent upon the passive or second subassembly 40 selected.
10 The section 78 or 79 then provides characteristics, determined from the target frequency response and the response characteristics of the passive speakers. The output of this section is then connected through to the section 80, which further modifies the response, dependent upon the characteristics of the subwoofer speaker.

15 Alternatively, for manual operation, for example with some wholly different passive speaker unit, the switch 92 is set to connect the output 102 through to the section 80. Then, the low pass frequency can be set using the potentiometers 106. As a further alternative, the input 112 can be used as the input to block 100, and again this is passed through the output 102 through
20 to the section 80.

 The section 80 has an output indicated at 96, connected through a connector 97, which is a five pin connector, providing connections both for the audio signal, and for receiving a power supply signal from the subwoofer amplifier, described below. A branch connector 98 is provided for auxiliary
25 connection for an indicator light.

 Turning now to Figure 5, the circuit for the subwoofer amplifier is shown. The subwoofer amplifier is again indicated generally at 24, as in Figure 1, and, by itself, is conventional to the assignee of the present invention.

 The amplifier 24 includes inputs 121 and, 122. The input 121 is
30 connected through to a protection circuit 124, which is configured to prevent overdriving of the subwoofer, and in particular is configured so that, if a user attempts to overdrive the subwoofer, the output signal is modified, to avoid unpleasant distortion effects. The input 122 can be connected to the audio signal for the passive speakers; this covers the whole frequency range, and

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ensures that, if just a high frequency signal is present, it will be detected, to maintain the subwoofer amplifier active.

The input 121 is also connected to a final power amplifier 126 including transistors 128, to amplify the signal to provide the necessary output
5 power. The final output of the subwoofer amplifier is indicated at 130, and would be paired with a corresponding reference terminal 132 connected to ground. In known manner, as is conventional for speakers, the output 130 would be indicated as red and the ground reference as black.

This subwoofer amplifier 24 includes an additional circuit 134 for
10 automatically turning the amplifier on and off. This circuit 134 is connected to the inputs 122, 123. It includes an amplifier 136, provided with threshold diodes 138, configured so that if the magnitude of the input signal at 122 is greater than 0.6V, the output of the amplifier 136 rapidly changes. This output is connected through to a transistor 130 effectively turning the whole power
15 amplifier 136 on. A further amplifier 142 is configured as a timing circuit, and turns the whole subwoofer amplifier 24 off if no signal of magnitude greater than the 0.6V threshold is detected after a period of five minutes.

Figure 5a shows the power supply for the subwoofer amplifier, identified at 150. This can be largely conventional, and includes a bridge
20 rectifier 152 and smoothing capacitors 154, connected to positive and negative rails 156, 157. The rails 156, 157 are connected through transistors 158, 159 to positive and negative outputs indicated generally at 160 and 161, for connection to appropriate elements of the circuit as indicated.

While the invention has been described as including a switch 92 in
25 the first subassembly, to enable switching between different characteristics, corresponding to different, known second subassemblies, other techniques are possible. For example, the first subassembly can be provided with some sort of sensor to automatically sense the presence of different second subassemblies. One simple way to achieve this would be to provide a switch or series of
30 switches on top of the first subassembly, which is mechanically actuated by some projection from the second subassembly, and each second subassembly could then be provided with an appropriate projection. Alternatively, this could be done in some remote manner, by use of some transmitting electrical or magnetic signal.

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Other possibilities for the individual components or subassemblies to recognize different subassemblies include: parameter sensing circuitry, position switches, and user controlled switches.

Reference will now be made to Figure 6, which shows a variant
5 or development of the present invention. The embodiment described above has been based on two speaker assemblies, one being an active, powered assembly and the other being a passive assembly. It is envisaged that the invention could be expanded to include three or more speaker assemblies, including a mixture of active and passive subassemblies, or just all active
10 subassemblies, or just all passive subassemblies. In this Figure 6 like components are given the same reference numeral as in earlier figures, the description of these components is not repeated.

The speaker enclosure of the first speaker subassembly 10 is again indicated at 14. Within it, as indicated above in Figure 4 there are located
15 the level control sections 74, section 78, 79 and 100 for adjusting or filtering the signal, the common section 80, the subwoofer amplifier 120 and the subwoofer 122 itself.

The selection switch 92 is indicated here as two separate switches 92a, 92b. 92a is a mode switch for switching between a solo or manual mode, in
20 which the speaker assembly 10 is not connected to any specific assembly 40. In this mode, as described above, the equalization circuit 70 can be adjusted manually as desired, and usually will be adjusted manually to achieve a best match with some other passive speaker unit.

In the alternative, connected mode, the signal is switched through
25 the second switch indicated at 92b, which enables switching through either the filter section 78 or the filter section 79, again as detailed above.

Figure 6 also shows a power source 160 connected to the speaker enclosure 14 and an audio amplifier 162 providing the original audio signal to the speaker enclosure 14.

30 Now, it is recognized that, in addition to the powered or active first speaker assembly 12, there could be an additional powered or active speaker assembly. This is identified using the same reference numerals but with a prime indication to distinguish; thus, this additional speaker assembly is identified as 12'.

The individual elements of this additional powered or active speaker assembly 12' are identified correspondingly. It can be noted that an audio signal connection is provided as indicated at 164, which can be either for a single channel or a multiple channel, depending upon the nature of the speaker. The description above has been for a single channel speaker, but it will be recognized that the speaker assembly 12', or indeed any of the speaker assemblies could be multi-channel assemblies, or at least capable of further transmitting two or more audio channels on to other speaker assemblies. As this speaker assembly 12' is powered, a power connection is provided at 166.

As indicated at 40, the second loudspeaker subassembly could be provided on top of or otherwise connected to the additional powered speaker assembly 12'. A connection at 168 is indicated, for the mechanical and electrical connection between the units 12', 40, which, for this passive unit, need only provide a connection for the audio signal.

Accordingly, the combined assembly, comprising the speaker subassemblies 12, 12' and 40 would comprise two powered or active subassemblies and the passive subassembly 40. As noted above, in general, any desired combination of active and passive components can be provided.

With respect to the connections 164, 166, each of these provides the necessary electrical connection. The mechanical interconnection can be provided, if desired, integral with one or other, or both, of the electrical connections 164, 166.

It is envisaged that a complete line of loudspeakers could comprise three alternative subwoofers, a first loudspeaker assemblies 12 and four passive or second loudspeaker assemblies 40, sometimes called satellite speakers. In a practical embodiment, there are restrictions as to which units can be combined together, because of size, etc.; overall, this yields six possible combinations.

It can be noted that the equalization circuit and the amplifier for the subwoofer can be implemented in various ways. Here, subtractive filters are used, but other known techniques are possible. Also, there could be greater integration between the equalization circuit and the subwoofer amplifier.

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CLAIMS:

1. A loudspeaker system comprising:
a first speaker assembly;
a second speaker assembly; and a
5 a coupling means for providing a mechanical and electrical interconnection between the first speaker assembly and the second speaker assembly, the coupling means being adapted to interchangably connect the first speaker assembly to a different second speaker assembly having different audio response characteristics from the first-mentioned second speaker
10 assembly;
wherein the first speaker assembly includes an equalization circuit for providing a signal to the second speaker assembly, the equalization circuit having an output for connection to the second speaker assembly through the coupling means, wherein the equalization circuit is switchable to
15 provide different outputs, each corresponding to the characteristics of a respective second speaker assembly.
2. A loudspeaker system as claimed in claim 1, wherein the first speaker assembly includes at least one first loudspeaker and a first amplifier therefor, and wherein the second speaker assembly includes at least one
20 second loudspeaker.
3. A loudspeaker system as claimed in claim 2, wherein the first speaker assembly includes a speaker adapted to cover a low range of frequencies, and the second speaker assembly is adapted to cover a higher frequency range.
- 25 4. A loudspeaker system as claimed in claim 3, wherein the coupling means provides a pair of electrical connections between the first and second speaker assemblies, for an audio signal from the first speaker assembly to the second speaker assembly, for driving the second speaker assembly.
5. A loudspeaker system as claimed in claim 4, wherein the electrical

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connections of the coupling means includes mechanical connections between the first and second speaker assemblies integral therewith.

6. A loudspeaker system as claimed in claim 5, wherein the coupling means comprises two pairs of first and second coupling elements, with the first
5 coupling elements being secured to the first speaker subassembly and the second coupling elements being secured to the second speaker subassembly, the coupling elements being complementary and engagable with one another to provide a mechanical connection and being conductive to form pairs of electrical connections.
- 10 7. A loudspeaker system as claimed claim 3, wherein the equalization circuit comprises an amplification and equalization circuit, for providing a drive signal to the low frequency speaker and including switch means enabling at least one of, the upper end of the low pass frequency range, and the phase to be adjusted.
- 15 8. A loudspeaker system as claimed in claim 7, wherein the amplification and equalization circuit includes a switch means for switching between at least one fixed filter mode, providing set parameters corresponding to a known second loudspeaker assembly, and a manual mode in which the amplification and equalization circuit can be manually adjusted.
- 20 9. A loudspeaker system as claimed in claim 8, wherein the amplification and equalization circuit comprises an amplification circuit and a separate equalization circuit.
- 25 10. A loudspeaker system as claimed in claim 9, wherein the equalization circuit includes an output section having parameters relating to a desired loudspeaker response and the response characteristics of the low frequency speaker, at least one additional section having parameters corresponding to a desired target response and parameters of a known second speaker system, thereby to give accurate compatibility between the first and second loudspeaker systems.

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11. A loudspeaker system comprising:
a first speaker assembly;
a second speaker assembly;
a connection means providing at least one of a mechanical
5 connection and an electrical connection between the first and second speaker
assemblies; and
an equalization circuit in the first speaker assembly including at
least two separate sections for adjusting the frequency response to match
different second speaker assemblies; and switch means for switching between
10 the different sections of the equalization circuit.
12. A loudspeaker system as claimed in claim 11, wherein the
equalization circuit includes at least one section with fixed parameters and at
least one section including manual control of at least one of low pass frequency
range, phase shift and amplitude level.
- 15 13. A loudspeaker system as claimed in claim 12, wherein the
equalization circuit includes subtraction filters.
14. A loudspeaker system as claimed in claim 13, wherein the first
loudspeaker assembly includes an amplifier connected to an output of the
equalization circuit, and a low frequency speaker connected to and driven by
20 the amplifier.
15. A method of selecting and assembling a loudspeaker assembly,
the method comprising the steps of:
(1) providing three or more first and second speaker
assemblies, each first speaker assembly comprising a low frequency speaker
25 and an amplifier for driving the low frequency speaker, and each second
loudspeaker assembly comprising at least one passive speaker, and there being
at least one first speaker assembly and at least one second speaker assembly;
(2) providing coupling means on the first and second speaker
assemblies, enabling each first speaker assembly to be coupled to each second

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speaker assembly;

(3) permitting an end user to select a desired pair of a first speaker assembly and a second speaker assembly;

(4) coupling together the selected pair of first and second
5 speaker assemblies.

16. A method as claimed in claim 15, which additionally includes providing an equalization circuit in the first speaker assembly, the equalization circuit including a plurality of filter sections corresponding to different second speaker assemblies and a selection switch, and the method further comprising
10 actuating the selection switch to select a filter section corresponding to the selected second loudspeaker assembly, thereby to provide accurate matching between the response characteristics of the first and second loudspeaker assemblies.

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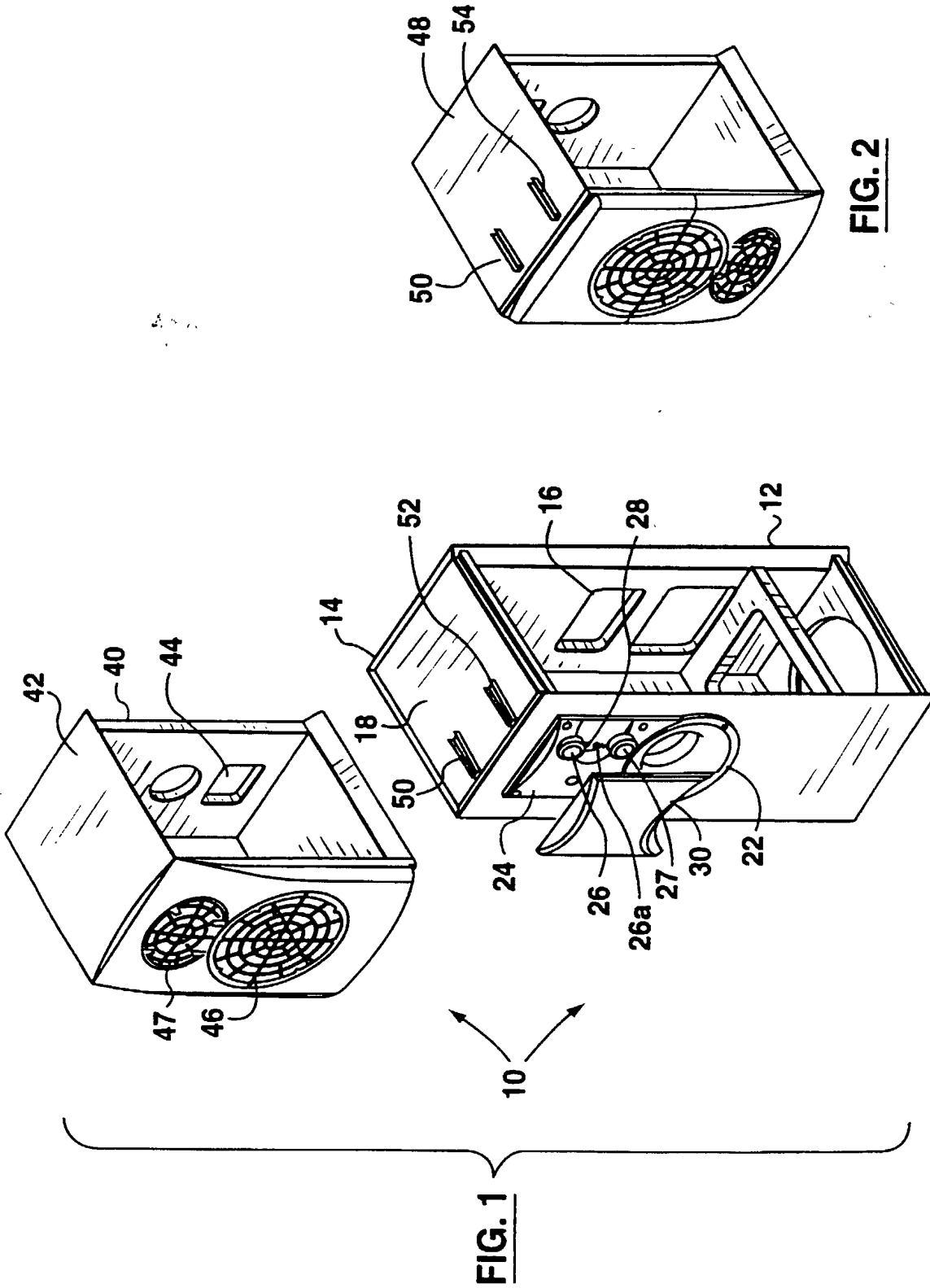


WO 01/22771 A2

(54) Title: **LOUDSPEAKER SYSTEM AND METHOD OF ASSEMBLING A LOUDSPEAKER SYSTEM FROM LOUDSPEAKER SUBASSEMBLIES**

(57) Abstract: A loudspeaker system has first and second loudspeaker assemblies, for example a powered, subwoofer assembly, and a passive subassembly. A mechanical and electrical connection is provided between the two subassemblies. This enables an end user to select different pairs of subassemblies, for matching and use together. To ensure accurate matching between the two assemblies, a filter circuit can be provided in the first subassembly, to filter the signal to the low frequency or subwoofer speaker, to give accurate matching with the known characteristics of passive speakers in the second subassembly. The first subassembly can include a switch to enable switching between different modes, corresponding to different second subassemblies.

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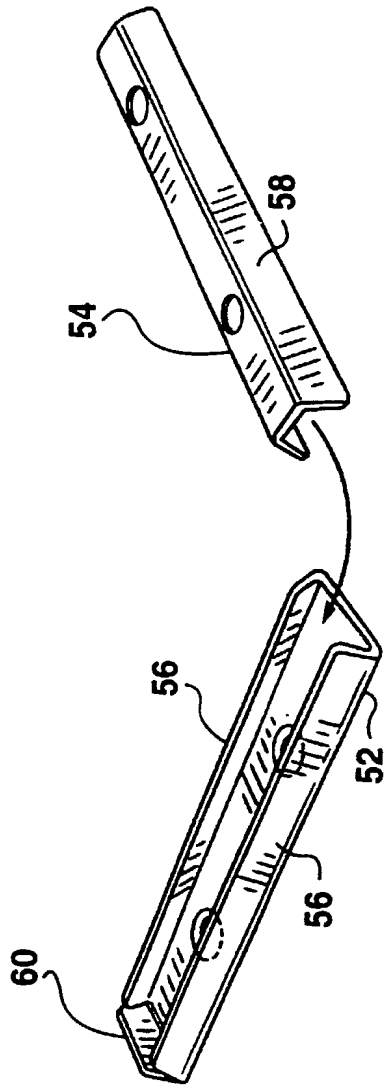


FIG. 3a

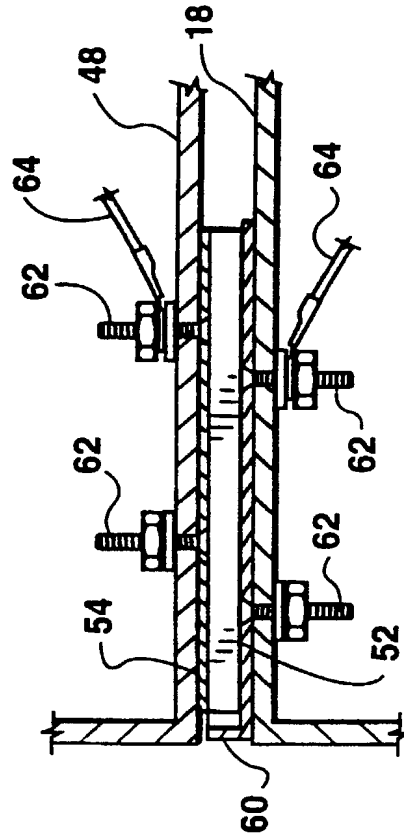


FIG. 3b



FIG. 3c

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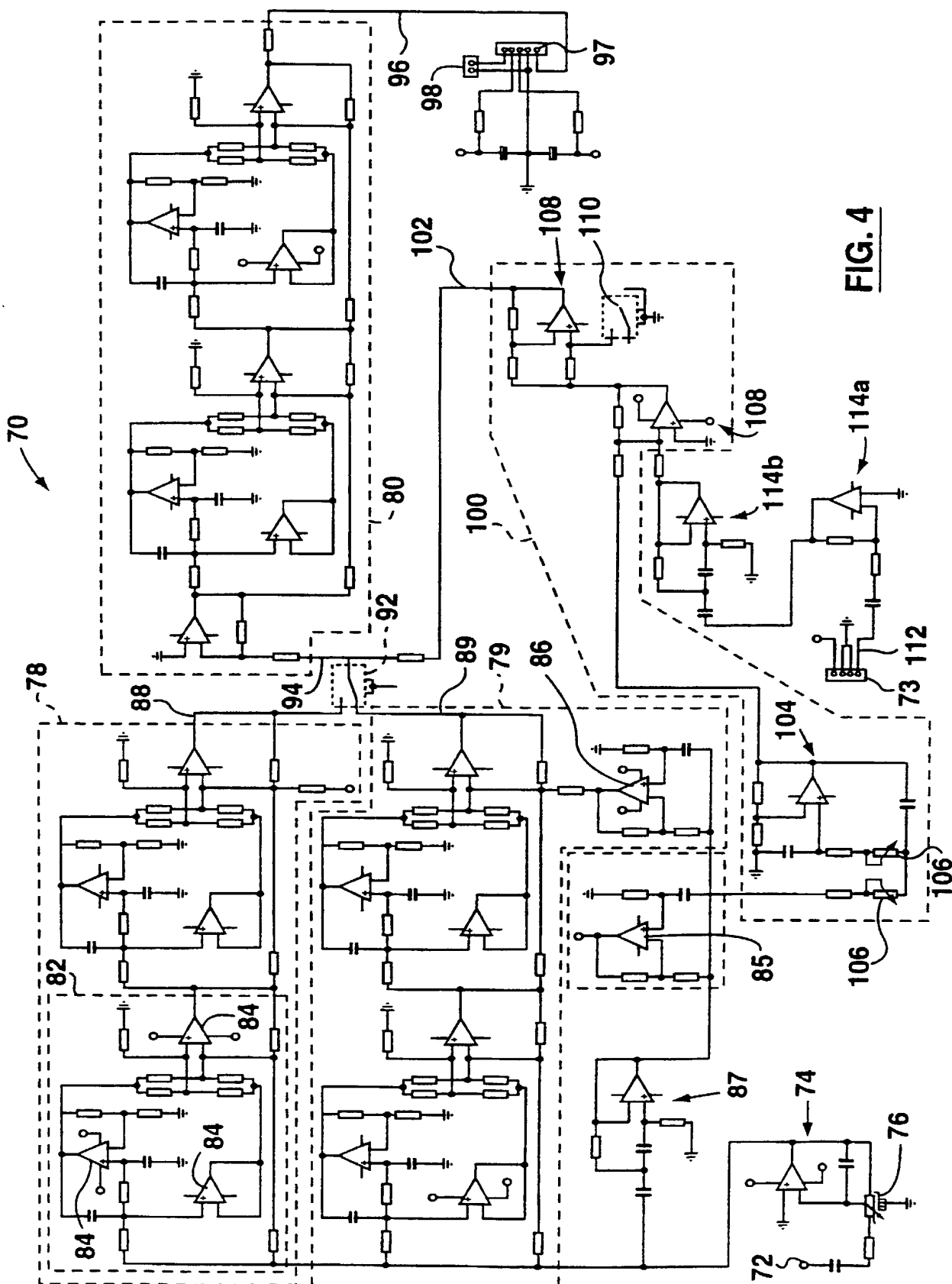
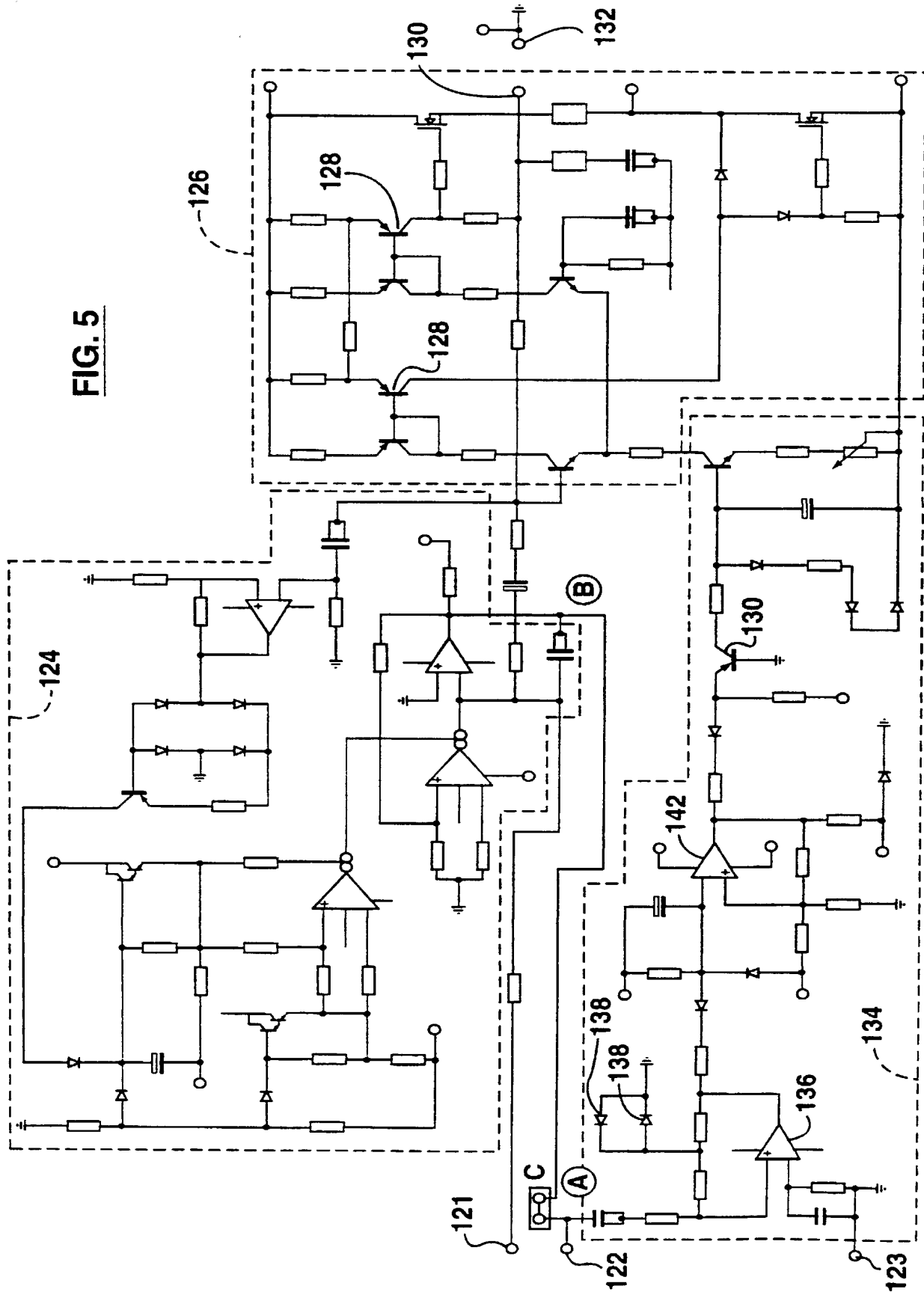


FIG. 4

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FIG. 5



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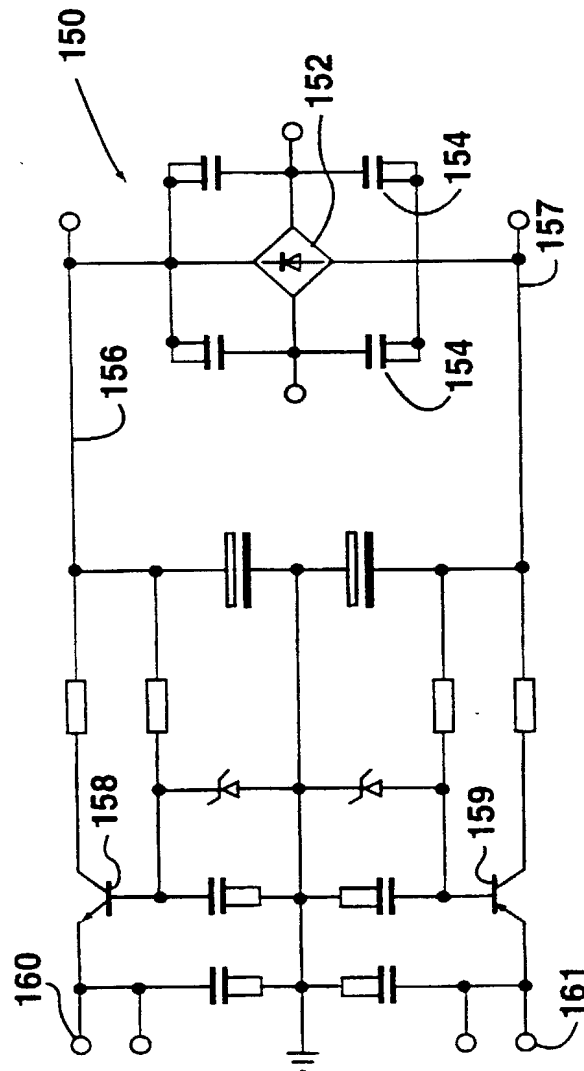


FIG. 5a

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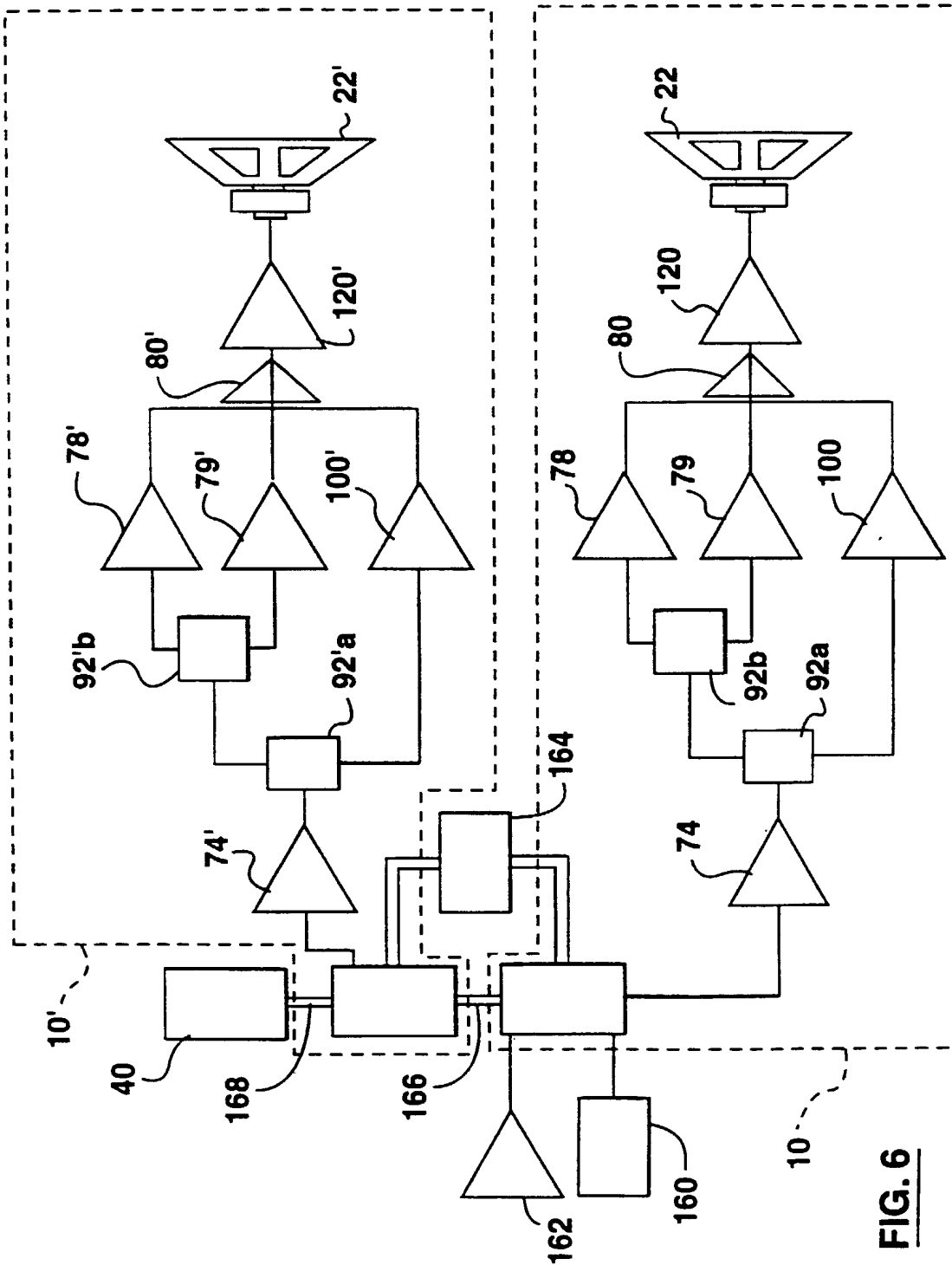


FIG. 6

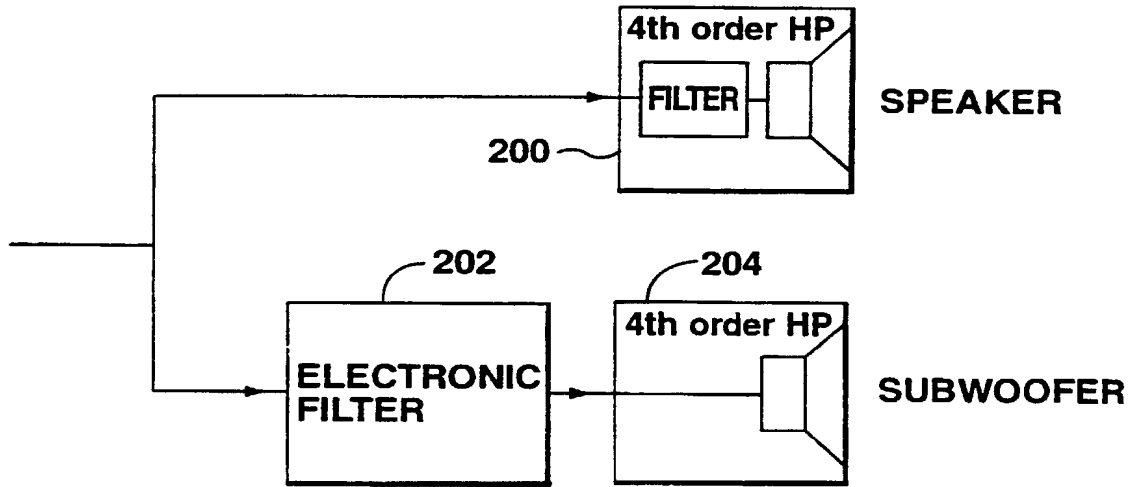


FIG. 7

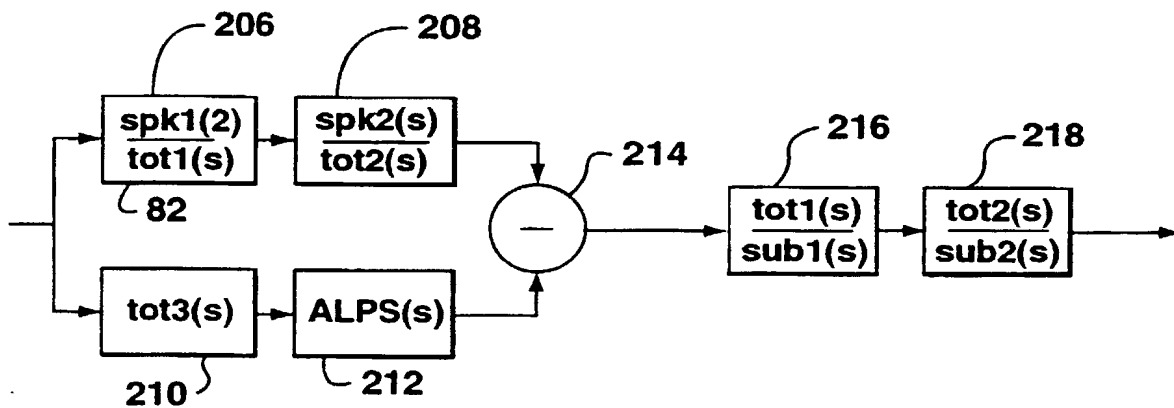


FIG. 8

**DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION
USING AN APPLICATION DATA SHEET (37 CFR 1.76)**

Title of Invention **LOUDSPEAKER SYSTEM AND METHOD OF ASSEMBLING A
LOUDSPEAKER SYSTEM FROM LOUDSPEAKER SUBASSEMBLIES**

As the below named inventor(s), I/we declare that:

This declaration is directed to:

- ☒ The attached application, or
☐ Application No _____, filed on _____
☐ as amended on _____ (if applicable).

I/we believe that I/we am/are the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought.

I/ we have reviewed and understand the contents of the above-identified application, including the claims, as amended by any amendment specifically referred to above.

I/we acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me/us to be material to patentability as defined in 37 CFR 1.56 including material information which became available between the filing date of the prior application and the National or PCT International filing date of the continuation-in-part application, if applicable, and

All statements made herein of my/own knowledge are true, all statements made herein on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001, and may jeopardize the validity of the application or any patent issuing thereon.

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Inventor three:

Signature: _____ Citizen of: _____

Inventor four:

Signature: _____ Citizen of: _____

☐ Additional inventors are being named on _____ additional form(s) attached hereto.

Burden Hour Statement. This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is used by the public to file (and the PTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This form is estimated to take 1 minute to complete. This time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.